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(71) Applicant(s)
Engineering for Industry Limited

(Incorporated in the United Kingdom)

Park House, 1A Park Road, BLACKBURN, Lancashire, BB2 3DJ, United Kingdom

Magellan Company Limited

(Incorporated in the Russian Federation)

22 Olimpiysky Prospect, 12910 Moscow, Russian Federation

(72) Inventor(s)
Stanislave G Belkin
Ernest A Volgemut
Igor B Dubin
Vladimir B Zak

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E21B 47/18

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(72) cont
Alexander M Kaplunov
Boris V Sokolov
Igor M Shepkin

(74) Agent and/or Address for Service
Urquhart-Dykes & Lord
3rd Floor, Victoria Suite, Northern Assurance Buildings, Albert Square, MANCHESTER, M2 4DN, United Kingdom

(54) Measurement-while-drilling system for wells

(57) Measurement while drilling (MWD) apparatus comprises a down hole unit 16, a surface unit 18 and a mud motor 20. The down hole unit (16) includes an hydraulic pulse transmitter 22, a turbine driven electric alternator, an hydraulic unit, a parameter sensing unit and an electronic unit. The surface unit 18 is connected to a flow rate sensor 24 and a pressure sensor 26.

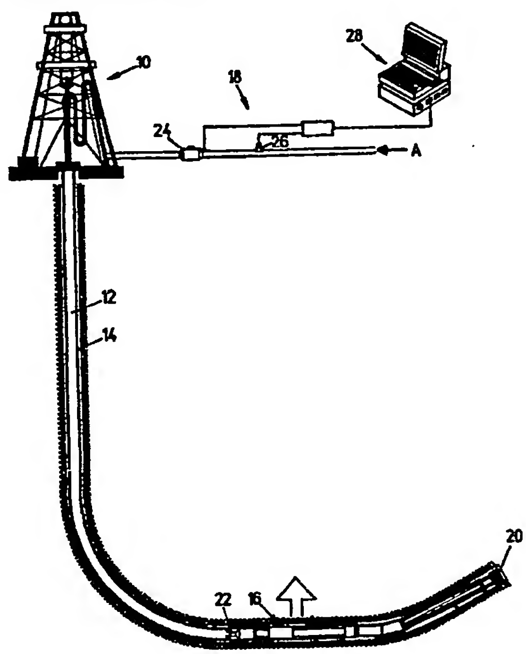

FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.

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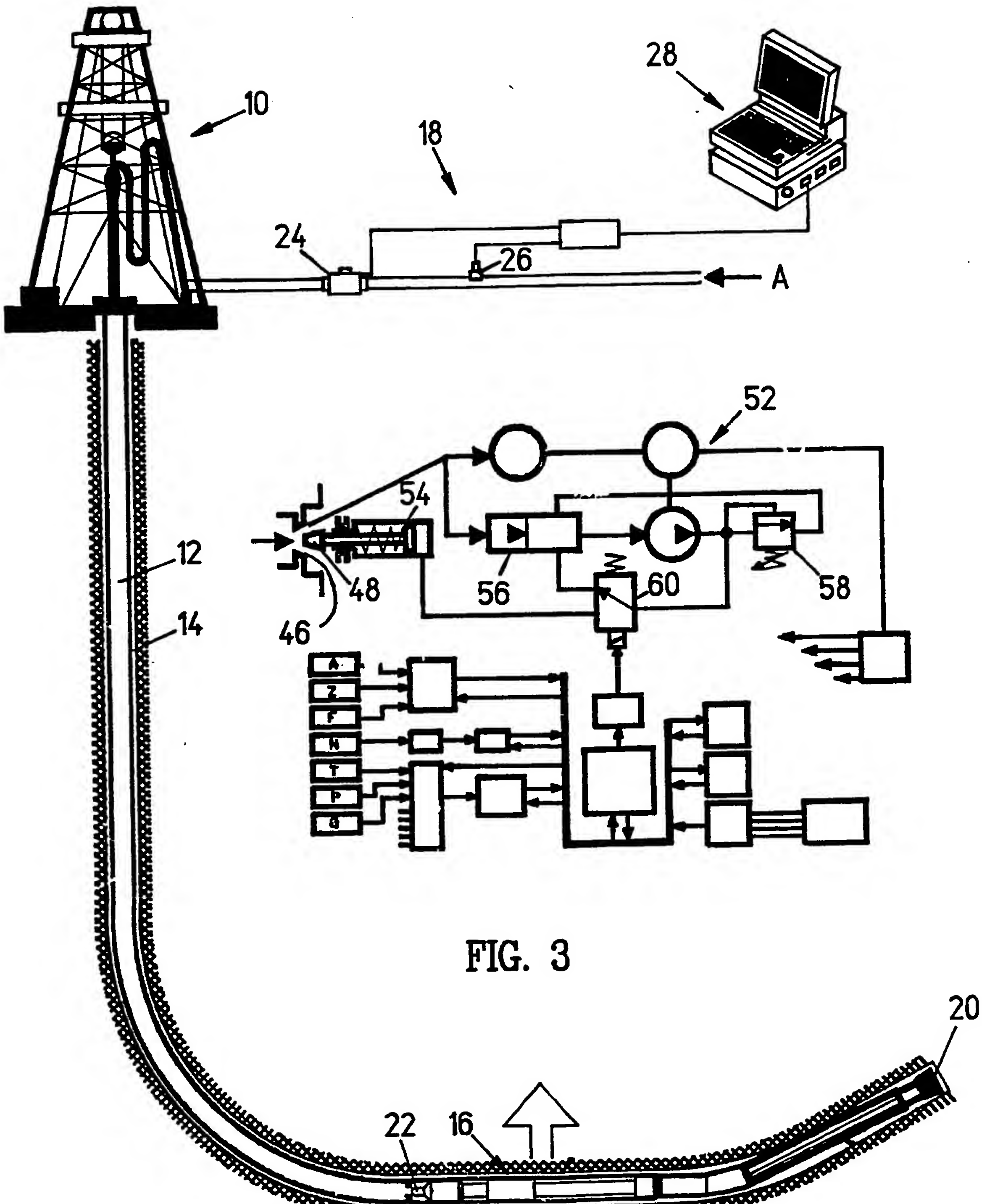

FIG. 3

FIG. 1

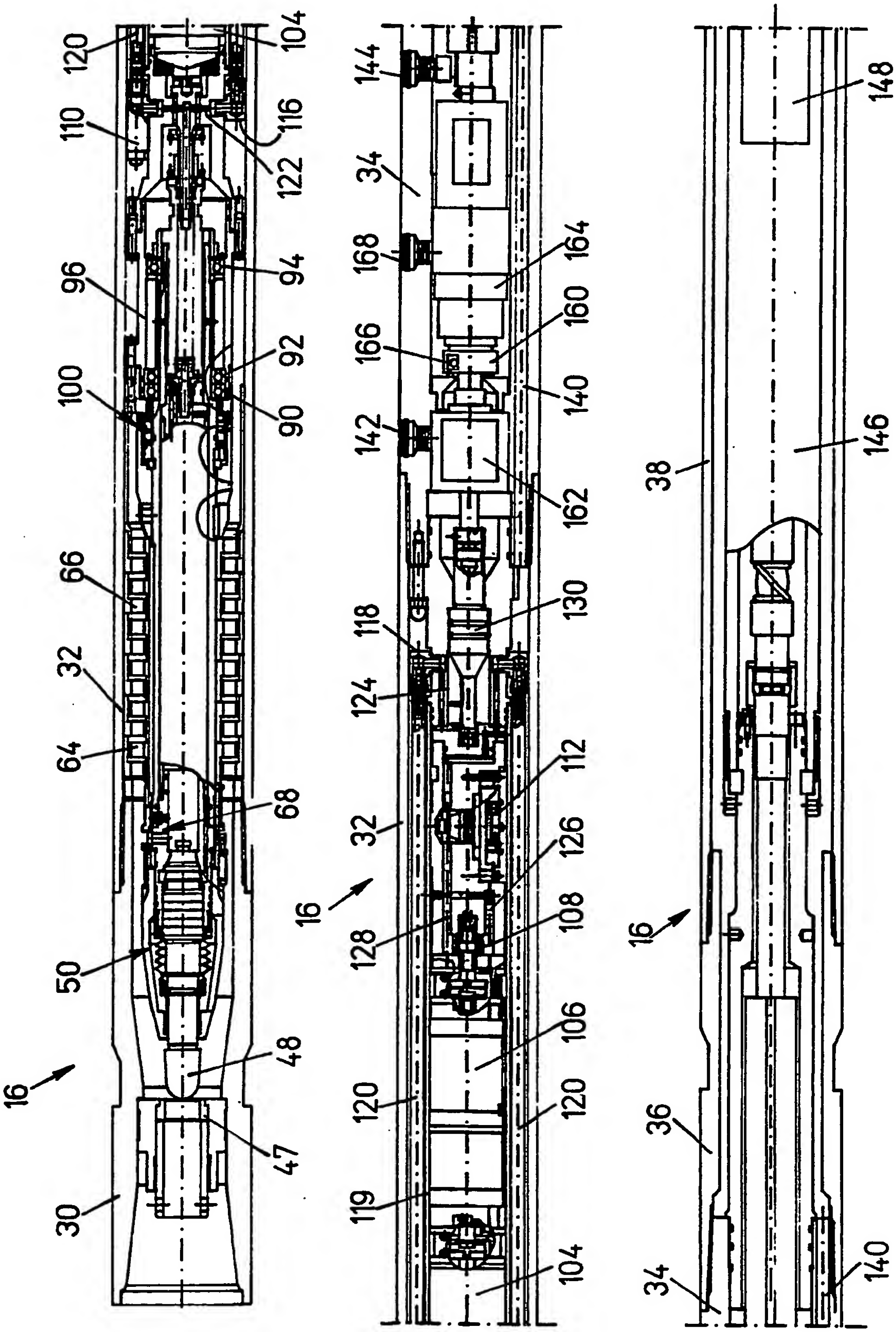

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FIG. 2

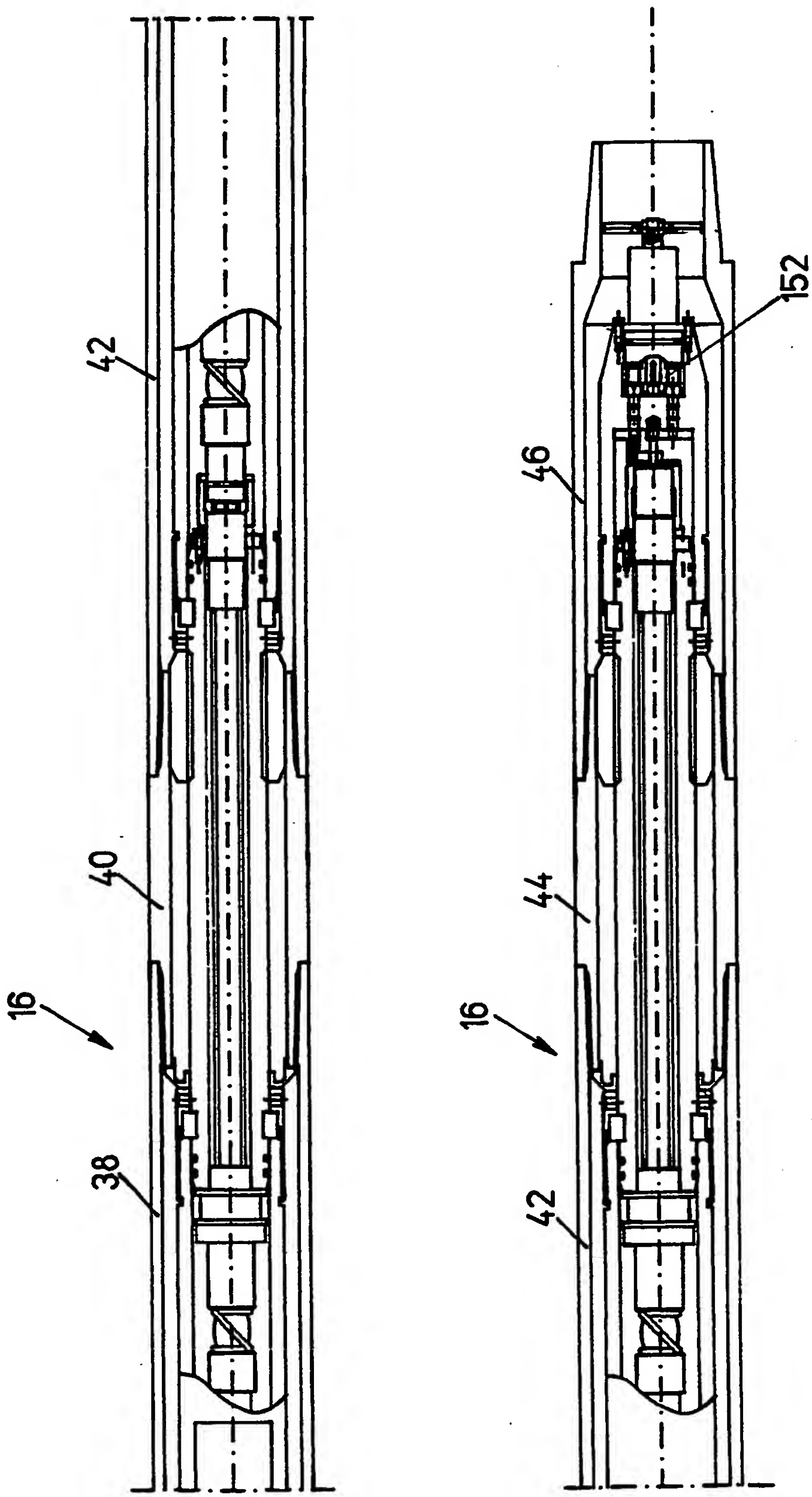

FIG. 2

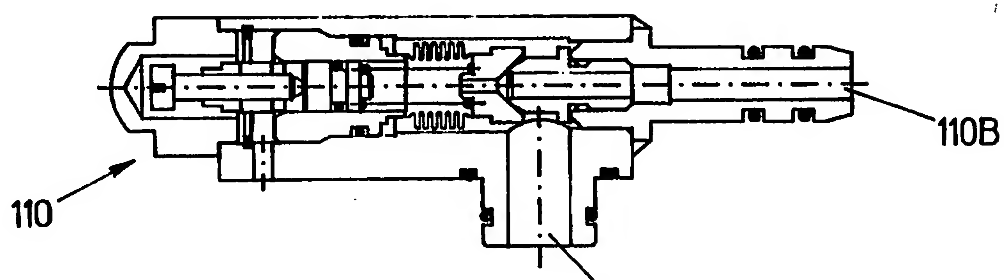

FIG. 5

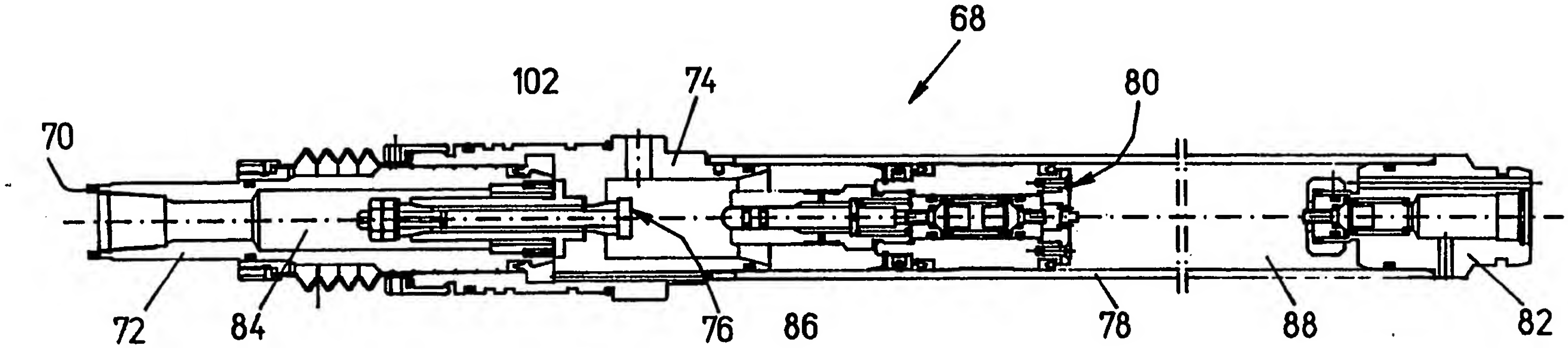

FIG. 4

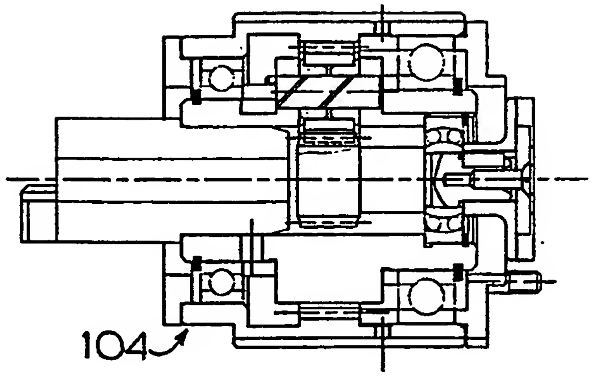

FIG.6

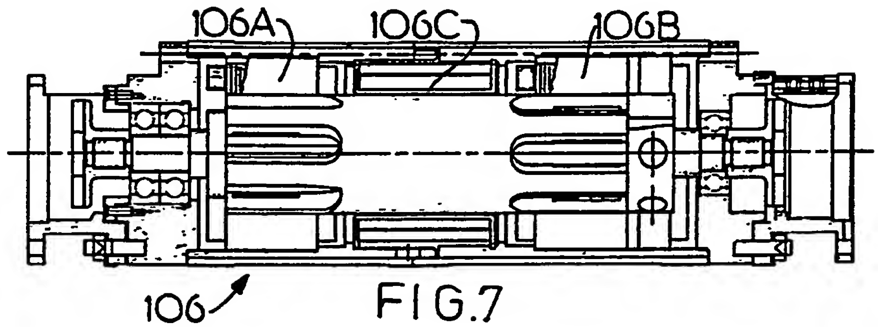

FIG.7

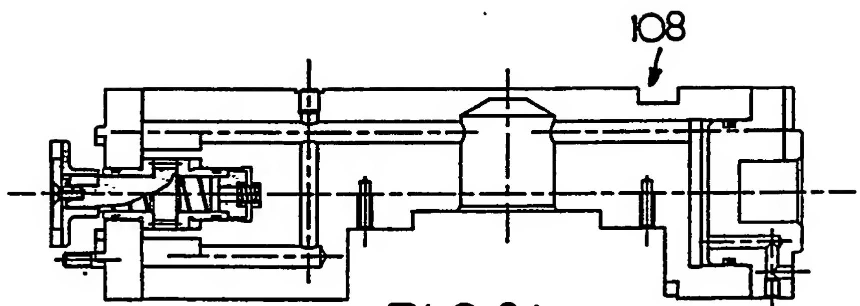

FIG 8A

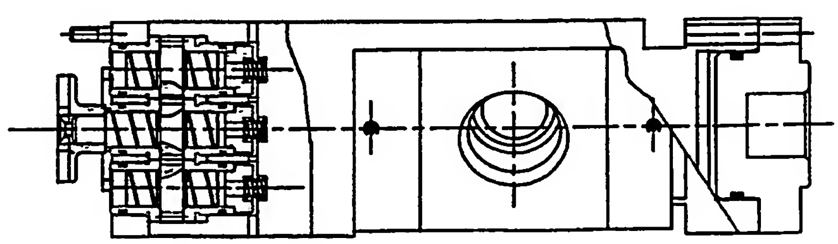

FIG 8B

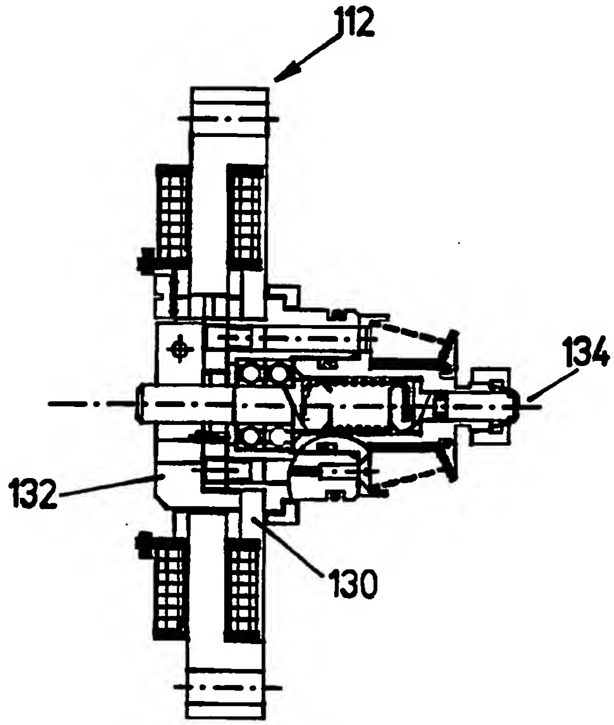

FIG. 9A

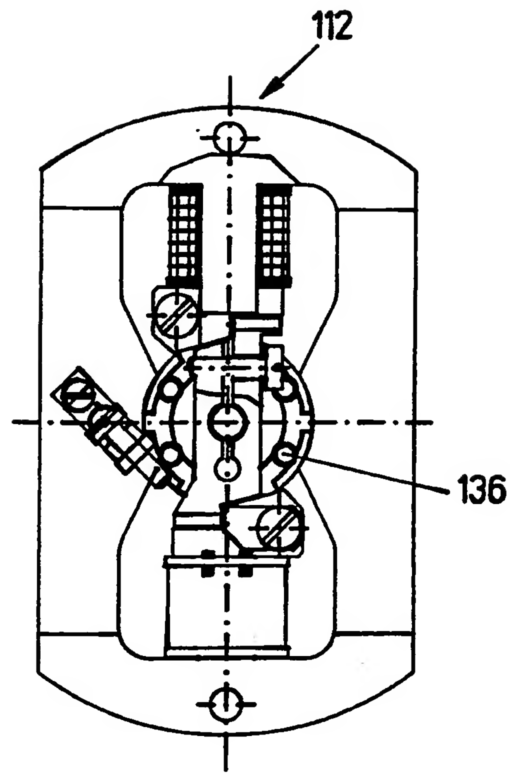

FIG. 9B

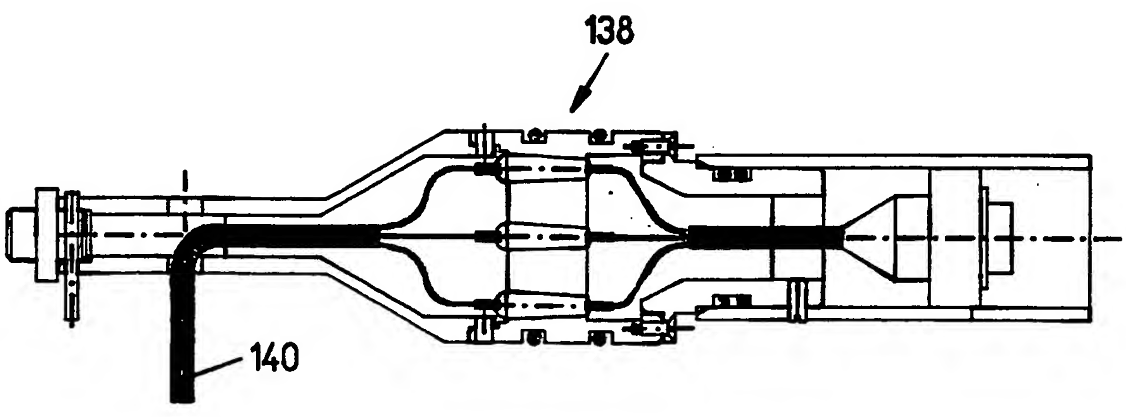

FIG. 10

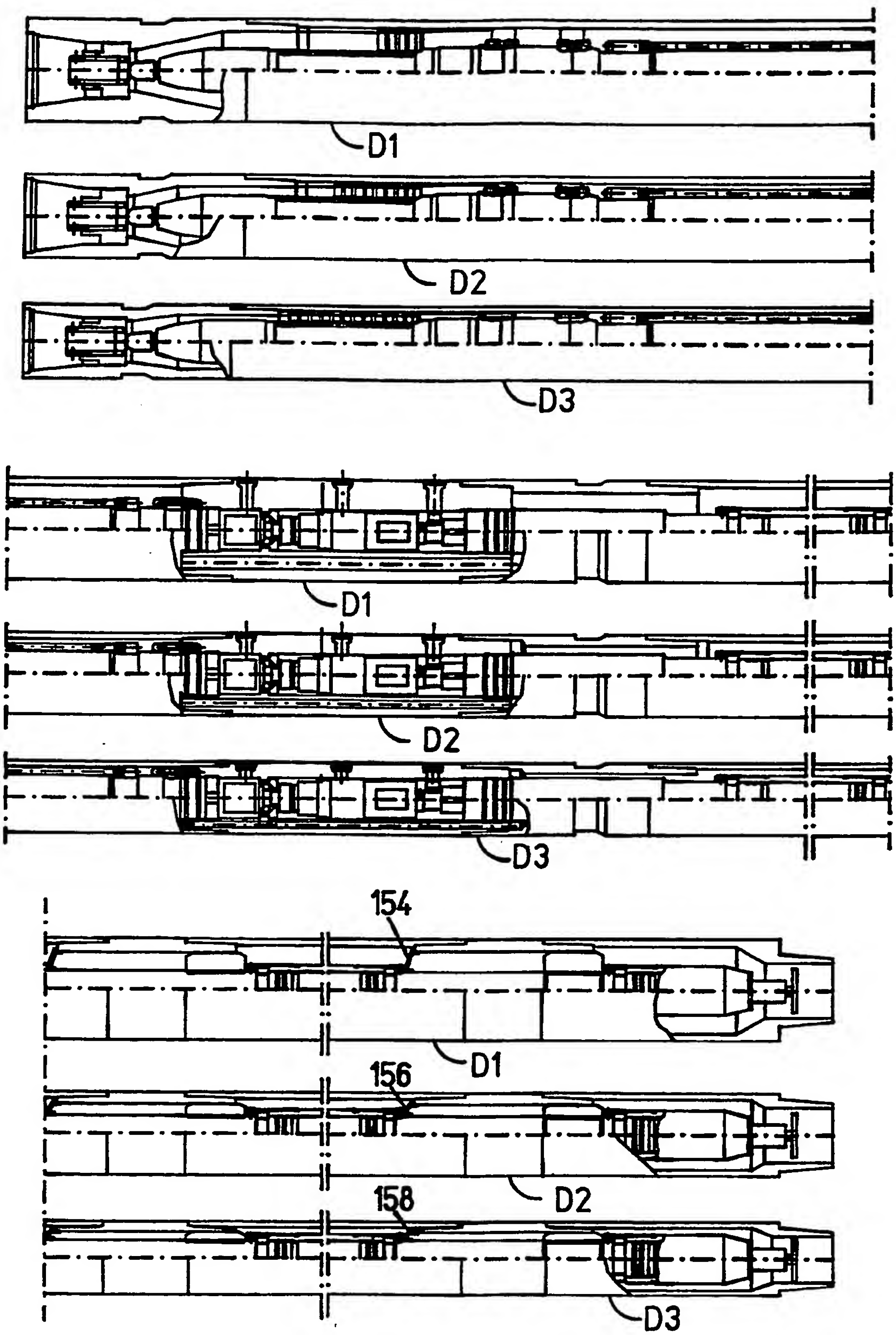

FIG. 11

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Improvements in or relating to the measurement while drilling (MWD) of wells.

The most widely used technology of drilling oil and gas wells involves the use of specially formulated muds which are pumped to the well bottom in order to remove slime, to rotate the mud motor and to cool the bit. On the surface the mud is filtered and separated from the slime for re-usage.

In the process of vertical, directional and horizontal drilling it is necessary to control the trajectory of the well. Information is required at the surface concerning the position of the drill bit whether it be a direct, directional or horizontal well; the conditions, as indicated by a number of parameters in the well, and geological data.

This type of information is provided by a number of available types of apparatus in which the values of a number of indicative parameters are obtained and the processed information is transmitted to the surface in the form of pressure waves through the mud flow in the drill string.

This type of apparatus and method of operating the apparatus is commonly known as measurement while drilling (MWD). The apparatus commonly consists of a down hole unit and a surface unit. The down hole unit includes a transmitter, sensors, transducers and a data processing unit.

The surface unit receives the information, processes that information and enables the information to be displayed or printed.

Known types of MWD are shown in United States patent number 4 184 545, UK patent number 2 123 458, Soviet Inventors Certificate Numbers 1 288 287, 1 486 596, 1 486 601, 1 490 268 and Soviet patent number 1 813 119.

These types of MWD and other known types of MWD have advantages but also a number of disadvantages.

For example the transmitter which is usually an hydraulic transmitter comprises a valve seat and a reciprocating closure member. This valve is prone to wear for example due to foreign bodies in the mud flow. Also the valve is difficult to replace quickly.

The hydraulic operating system of the transmitter does not necessarily provide an hydraulic signal amplitude which is

constant irrespective of mud flow rate and wear of the transmitter valve, this latter feature being desirable.

The power unit of the transmitter tends to be large and bulky which increases the size and weight of the down hole unit.

The power unit as a whole can also be relatively large and the present invention seeks to provide a power unit in which the alternator size can be reduced and also decreases the internal heating of the transmitter during wide range fluctuations of the mud flow rate.

Also not all existing systems have the ability to control level of oil and to prevent failure of the hydraulic system in the case of a complete loss of oil.

The present invention seeks to provide a compensating means for the transmitter making it possible to control the level of oil and to prevent failure.

Hydraulic systems also tend to be relatively large and the present invention seeks to provide a means of reducing the size of the hydraulic system by the design of the components which fasten the parts of the power unit together.

The present invention also seeks to provide a means of preventing

mud leakage into the oil at the location between the rotating and static parts of the down hole unit.

The present invention also seeks to provide a means of detecting leakage in the drilling column.

The present invention seeks to provide a down hole unit which is in modular form so that modules of the unit can be interchanged and manufacturing, transportation, assembly, adjustment and repair are improved.

The hydraulic system includes a particular form of valve having its axis perpendicular to that of the down hole unit. This construction prevents the influence of vibrations along all axes on the accuracy of the valve operation; reduces friction in the valve; provides linearity of characteristics; allows electric monitoring of the hydraulic pulse amplitude and improves sensitivity and operating a transmission rate of the hydraulic system.

Overall the invention seeks to improve the reliability of operation of the down hole unit of the telemetry system, of separating down hole information from hydraulic and other interference as well as obtaining further down hole information in order to improve the economic characteristics of drilling.

Accordingly the present invention provides measurement while

drilling apparatus for use in the drilling of vertical directional and horizontal oil, gas and other wells with an hydraulic line of communication via the mud column, the apparatus including a positive hydraulic pulse transmitter, an automonous hydraulic oil operating system, a turbo electric alternator, a hydro unit, a parameter sensing unit, an electronic unit including data processing means, a means of recording long term storage of information together with a surface unit for decoding and displaying down hole information.

The shaft of the transmitter unit is preferably rotatable, and is driven by a turbine, the mud flow driving the turbine.

A modulating valve can be provided on the shaft of the transmitter unit.

The hydraulic operating system of transmitter can have an adjustable hydraulic signal amplitude.

The signal amplitude can be tuneable in relation to the well depth and to damping of signal in the hydraulic line to provide separation of the signal from interference.

The power unit of the transmitter can have a multiplier, in order to reduce the size of various components of the power unit, such

as the electro-alternator and hydraulic pump.

The alternator can have a single stage rotor and a two stage stator.

The transmitter includes means to monitor upper and lower positions of a compensator plunger, in order to control oil level and prevents failure of the hydraulic system in the event of a complete loss of oil.

The parameter sensing unit has a mud bypass flow through peripheral holes, leaving a central passage in order to position an indicator of axial weight-on-bit; provides convenient access to the annulus; allows test connection externally before lowering into the well; and to place special plugs for different operating modes, including those for altering the hydraulic pulse amplitude.

The power unit assembly has components which can also be used as a system for cooling the oil, thereby reducing the volume of oil needed, and thus the size of the hydraulic system.

Open rotating end seals are provided to prevent mud leakage into the oil cavity, and to exclude penetration of the solid phase into the oil cavity.

The alternator frequency can be used to measure the input mud flow rate, making it possible to detect leakage in the drilling column.

A disconnector can be provided between the transmitter and sensor unit, enabling failure of any unit to be quickly detected.

The down hole unit can be constructed in complete functional modules, so improving, manufacture, transportation, subsequent assembly, repair, overhaul and interchangeability.

The weight-on-bit sensor can include a reducer so that sensitive components can be pre-tightened before lowering the downhole unit into the well.

The weight-on-bit sensor can include a temperature sensor inside the casing of the down hole unit which with the annulus temperature sensor makes it possible to eliminate a temperature error of the weight-on-bit measuring data channel.

The hydraulic unit can have a rotating disc valve, the axis of the valve being perpendicular to the axis of the down hole unit.

Non-magnetic drilling pipes are preferably used having the same electrical potential as drilling pipes made of steel, in order to prevent corrosion in the threaded joints.

A pressure sensor and a flow rate sensor are provided at the surface unit.

The present invention will now be more particularly described with reference to the accompanying drawings in which;

Figure 1 shows a general arrangement of one form of MWD apparatus according to the present invention;

Figure 2 shows in more detail the MWD apparatus shown in figure 1;

Figure 3 shows a transmitter valve modulator of the apparatus shown in figure 2;

Figure 4 shows in detail a transmitter compensator of the apparatus shown in figure 2;

Figure 5 shows a signal amplitude adjusting unit of the apparatus shown in figure 2;

Figure 6 shows in detail a speed increasing gear box of the apparatus shown in figure 2;

Figure 7 shows an alternator of the apparatus shown in figure 2;

Figures 8a and 8b show two views of a pump of the apparatus shown in figure 2;

Figures 9a and 9b show two views of an electrically operated hydraulic valve of the apparatus shown in figure 2;

Figure 10 shows an hermetically sealed unit of the apparatus shown in figure 2;

Figure 11 shows three sizes of MWD apparatus according to the present invention.

Referring to figure 1 there is shown diagrammatically a well which can be for example an oil or gas well having a well head (10) a drill string (12) positioned in a well bore (14) and MWD apparatus comprising a down hole unit (16) and a surface unit (18). At the far end of the down hole unit (16) there is provided a mud motor (20).

The down hole unit (16) includes an hydraulic pulse transmitter (22) which sends signals in the form of pulses through the mud column in the drill string (12) to be received by the surface unit (18).

Mud for the mud column is supplied from a pump (not shown) through ducting in the direction of arrow A and the flow rate and pressure of this mud flow are sensed by a flow rate sensor (24) and a pressure sensor (26), this information being received by data processing and decoding apparatus which includes a computer (28).

The down hole unit (16) will now be more particularly described with reference to figure 2 which shows the down hole unit and the internal components in detail.

Casing formed by a number of housings and cylindrical tubes which are sequentially attached together and contain the operating components of the down hole unit.

The down hole unit essentially comprises a casing in which a number of housings and tubes are sequentially joined together the casing comprising a first housing (30) a first cylindrical tube (32), a second housing (34), a third housing (36), a second cylindrical tube (38), a fourth housing (40), a third cylindrical tube (42), a fifth housing (44), and a sixth housing (46).

It will be appreciated that the housings and tubes (30),(32), (34), (36), (38), (40), (42), (44) and (46) enable the down hole unit to be in a modular form which provides a number of benefits in terms of interchangeability, transportation, assembly and overhaul, each module comprising a functional unit.

The housing (30) includes an hydraulic transmitter unit which comprises a valve seat (47) which is secured to the housing (30) and a valve closure member (48) which can reciprocate under the influence of hydraulic pressure as will be described below to open and close the transmitter and thereby send impulses through the mud column to the surface unit (18)

The transmitter valve closure member is mounted on a rotatable shaft assembly (50) as is also a modulator (52) which is shown in more detail in figure 3. The modulator (50) includes a modulating valve (55) a compensator (56), and hydraulic valves (58) and (60) and a pump. The modulator (52) operates to ensure proportional wear of the valve and to enable rapid valve replacement without the need to open the oil reservoir. The gap between the valve member (48) and the seat (46) is monitored and if the gap increases to greater than a pre-determined value, the pump operates, the valve (60) opens to allow oil to be pumped in the modulator (54) and forcing the valve member (48) forward, closing the gap between the seat and the valve member. When the correct gap is reached the pump is switched off and pressure maintained.

It will be appreciated that the valve member (48) can be removed simply by releasing the valve seating (46) from the housing (30), detaching the valve member from its mounting and withdrawing the

valve member through the open end of the housing (30). (note to Magellan - please explain the other components of the modulator (52) if the explanation of how the modulator compensates for wear is not correct, please explain).

The shaft assembly (50) is driven by a turbine which comprises rows of rotor blades (64) which are mounted on the shaft and corresponding rows of stator blades (66) which are secured to the tube (32).

It will be appreciated that the mud flow enters the down hole unit through the intake to the housing (30) flows through the gap between the valve seat (46) and the valve member (48) into the annulus between the shaft assembly (50) and the casing of the down hole unit which is formed by the housing (30) and the tube (32) at this point thereby rotating the shaft assembly (50), the valve member (48) and the modulator (52).

Internally of the shaft there is an assembly (68) which acts both as a pressure compensator and to separate the mud flow from the hydraulic oil. The assembly (68) is shown in more detail in figure 4. The assembly (68) has at its forward end a dog clutch type connector (70) enabling the valve member (48) to be secured to the assembly (68). The assembly (68) comprises a number of components including two housings (72) and (74) which are secured together by a nut and bolt assembly (76), a tubular duct (78)

attached to the housing (76), a piston assembly (80) which is sealingly positioned within the duct (78), the end of the tubular duct (78) being closed off by an assembly (82).

It will be appreciated that internally of the assembly (68) there are a number of compartments which are sealed off from one another, these being a forward compartment (84), an intermediate compartment (86) and a down stream compartment (88). The compartments are required to be sealed from one another as the compartment (86) in use is flooded with mud whilst the compartment (88) comprises part of the hydraulic oil reservoir and it is necessary to prevent mud from entering the compartment (84) otherwise it would interfere with the function of the modulator (52) see figure 3.

Referring to figure 2 the shaft assembly (50) is rotatably mounted in bearings (90), (92) and (94) which are located in a bearing housing (96) secured to the tubular casing (32).

There is a gap indicated at (100) between the rotating shaft assembly (50) and the bearing housing (96) which is closed off by end seals.

As the mud flows through the turbine comprising the rotor blades (64) and the stator blades (66) there will be a pressure drop in the mud flow and therefore the mud pressure in the annulus

downstream of the turbine will be less than the mud pressure upstream of the turbine. However the pressure of the hydraulic oil in the reservoir which is on the otherside of the end seals at the gap (100) may be less than that pressure and therefore the compensator components of the assembly (68) function to maintain a greater pressure in the oil reservoir than the mud pressure downstream of the turbine.

In order to achieve this condition in operation mud flows not only through the turbine but also into the chamber (86) through an opening (102) in the housing (74). Thus the mud pressure exerts a pressure on the upstream end of the piston assembly (80) and thereby pressurises the hydraulic oil in the reservoir (88) in order to prevent mud flowing into the hydraulic oil at the gap (100). Instead there is a very slight flow of hydraulic oil into the mud but not such as to effect the qualities of the mud or to substantially reduce the volume of hydraulic oil. The main purpose of the compensator arrangement is to ensure that no mud enters the hydraulic oil.

The downstream end of the shaft assembly (50) drives the input to a speed increasing gear box (104) (see figure 6), the output of which drives an alternator (106) (see figure 7) and a pump (108) (see figures 8a and 8b).

It will be appreciated that the housing (30) together with the hydraulic impulse transmitter forms a transmitter module whilst

the shaft assembly and its internal components together with the speed increasing gear box (104), alternator (106), pump (108) together with other components inside the tube (32) form a power module.

The power module also includes a signal amplitude regulator (110), see figure 5 and an electro hydraulic valve (112), see figures 9A and 9B.

The speed increasing gear box (104), alternator (106), pump (108) and valve (112) are mounted within a frame comprising two end plates (116) and (118), four ducts (120), and an inner casing (119) which are secured between the end plates (116) and (118). Both end plates (116) and (118) are formed with internal channels which communicate with the interior of the tubes (120). The gear box alternator pump and valve are located within the casing (119) to isolate these components from the mud flow.

The internal channels in the upstream plate (116) communicate with the hydraulic oil reservoir via ducts (122) whilst the internal channels formed in the down stream plate (118) allow the hydraulic oil to flow into a space (128) which is in communication with the valve (112), the valve (112) being in communication with the pump (108) via ducts (126) and (128).

The hydraulic oil thus can be pumped from the reservoir (88) into the tubes (120) through the end plate (116) out of the end plate (118) and to the pump (108) under the control of the valve (112).

If the quantity of oil in the hydraulic reservoir falls to a dangerous level the mud pressure in the compensator (68) will force to the piston assembly (80) in the downstream direction and will open a valve which will decrease the hydraulic oil pressure. The decrease in this oil pressure will be indicated at the surface unit and the operator will shut down the down hole unit thereby preventing damage to the down hole unit which would otherwise occur should the hydraulic oil be completely lost.

When oil is pumped (while refilling) into the transmitter (cavity 88 figure 4) the piston (80) travels up to assembly (76) which is insulated from the housing. With the help of a special device placed in cavity (84) the occurrence of electric contact between assembly (76) and the housing of the transmitter can be detected which is a sign of filling the device with oil to capacity. At the same time, when piston (80) comes into contact with assembly (76), a safety valve (80A) on piston (80) opens either in order to restrict oil-pumping pressure or under temperature expansion.

The speed increasing gear box (104) enables the size of the alternator pump and pulse transmitter to be reduced as a whole.

The alternator (106) has two stators (106A) and (106B) and a single excitation winding (106C). This arrangement enables the size of the alternator to be reduced increases the alternator

capacity and reduces stabilising energy loss which in itself decreases the inner heating of the tool whilst wide range fluctuations of the mud flow rate take place.

The frequency of the alternator can be used to measure the input mud flow rate which combined together with measuring the mud flow rate from the surface unit makes it possible to detect any leakage in the drilling column.

Referring to figure 5, the signal amplitude adjustment unit (110) has a duct (110A) and a duct (110B). The duct (110A) is connected to the tank (low pressure cavity) and the duct (110B) is connected to the delivery side of the pump. When the pressure in duct (110B) exceeds a set value, the extra pressure is dropped from duct (110B) to duct (110A).

Referring to figures 9a and 9b the valve (112) is an electro hydraulic valve comprises rotor and stator plates (130) and (132) respectively the axis (134) of which is set perpendicular to the axis of the down hole unit. Under the influence of an electric signal from the down hole unit (16) the rotor plate rotates (130) with respect to the stator plate and gradually exposes or closes off openings (136) to allow or prevent hydraulic oil from passing to the pump.

The rotating disc valve (112) because of the arrangement of its

rotational axis has a number of advantages including; excluding the influence of vibrations along all axes on the accuracy of the valve operation; significantly reduces friction in the valve; provides linearity of characteristics; and allows electric monitoring of the hydraulic pulse amplitude and due to the few openings, sensitivity and transmission rate of the system is increased significantly.

A parameter sensor module comprising the casing (34) and its contents, is attached to the power module by a hermetic-connector (138) (see figure 10). The hermetic-connector (138) which is hermetically sealed prevents hydraulic oil from entering the sensors contained within the parameter sensor module and allows electrical signals to be conducted through cabling (140).

A mud by-pass is provided in the parameter sensor unit by means of holes (140), the mud having passed through the power module between the tubes (120) in the annulus between the casing (32) and the inner casing (119) surrounding the gear box, alternator, pump and electro hydraulic valve.

The provision of the mud by-pass (140) makes it possible to use the central passage of the casing (34) to position a weight-on-bit sensor (160), allows provision of convenient access the annulus; it further also allows the placing of a test connector or connectors (142) for testing the system before lowering the down

hole unit into the well in the presence of mud circulation and to provide special computational plugs (144) for the different operating modes of the MWD apparatus including those for altering the hydraulic pulse amplitude.

An electronic unit (146) and geometric sensors (148) are included in a further module, the geometric sensors detecting the position of the drill bit. The next down stream module can include geophysical sensors (150) if required in order to determine geological information of the well whilst in the extreme downstream module there is provided an RPM sensor (152) for the drive to the drill bit.

Referring to figure 11 the down hole unit can be easily adapted to a range of external diameters D1, D2 and D3. The internal components of the modules are identical to each but the casings, housings and tubular sections are in a number of outer diameters and it is only necessary to support the internal components from the different sized diameters of casings but means of suitable adaptors (154), (156) and (158) and varying the internal diameter of one or more of the casings.

The provision of a disconnecter (162) between the hydraulic pulse transmitter unit and the sensor unit enables the quick detection of failures of units.

It will further be appreciated that the down hole unit is assembled in the form of modular functional blocks which improves manufacturing, transportation, assembly, adjustment, repair overhaul and interchangeability.

The weight-on-bit sensor in the parameter sensor unit includes a reducer (164) which makes it possible to pre-tighten the sensitive component before running the down hole unit into the well.

The weight-on-bit sensor also includes a temperature sensor (166) inside the casing which together with an annulus temperature sensor (168) makes it possible to exclude a temperature error of the weight-on-bit measuring data channel.

At the surface unit (18) the signal is received using the pressure sensor (26) and a flow rate sensor (24) or two pressure sensors installed in different sections of the pressure line and at the same time double filtration is carried out by means of a filter. The transfer function of the filter is adjusted by test signal of pre-set form which is transferred from the bottom hole by request from the surface unit. The request is sent by means of switching on the drilling pumps for a short time which is shorter than a pre-set time. When the pumps are switched on the down hole processor is switched on and it tests the bit of transmitting condition of the test signal. This bit is stored in

the long term memory with an automonous power pack if the bit is set on 1 transmission of the test signal starts and when it is completed the bit drops to 0. If the bit is set to 0 the processor resets it to 1, starts the timer for counting the set time interval and starts transmission in normal mode and at the end of the time period drops the condition to 0.

Claims

1. Measurement while drilling apparatus for use in the drilling of vertical, directional and horizontal oil, gas and other wells with an hydraulic line of communication via the mud column, the apparatus including a positive hydraulic pulse transmitter, an automonous hydraulic oil operating system, a turbo electric alternator, a hydro unit, a parameter sensing unit, an electronic unit including data processing means, a means of recording long term storage of information together with a surface unit for decoding and displaying down hole information.

2. An apparatus as claimed in claim 1 in which the shaft of the transmitter unit is rotatable and is driven by a turbine, the mud flow driving the turbine.

3. An apparatus as claimed in claim 2 in which the transmitter unit shaft includes a modulating valve.

4. An apparatus as claimed in claim 1 in which the hydraulic operating system of the transmitter has an adjustable hydraulic signal amplitude.

5. An apparatus as claimed in claim 4 in which the signal amplitude is tunable in relation to the well depth and to damping of the signal in the hydraulic line to provide separation of the signal from interference.

6. An apparatus as claimed in claim 1 in which the power unit of the transmitter has a multiplier in order to reduce the size of various components of the power unit for example the electro alternator and hydraulic pump.

7. An apparatus as claimed in claim 6 in which the alternator has a single stage rotor and a two stage stator.

8. An apparatus as claimed in claim 1 in which the transmitter includes means to monitor upper and lower positions of a compensator plunger in order to control oil level and prevent failure of the hydraulic system in the event of a complete loss of oil.

9. An apparatus as claimed in claim 1 in which the parameter sensing unit has a mud bypass flow through peripheral holes leaving a central passage in order to position an indicator of axial weight-on-bit; provides convenient access to the annulus; allows test connection externally before lowering into the well; and to place special plugs for different operating modes including those for altering the hydraulic pulse amplitude.

10. An apparatus as claimed in claim 1 in which the transmitter power unit has components which can also be used as a system for cooling the oil thereby reducing the volume of oil needed and thus the size of the hydraulic system.

11. Apparatus as claimed in claim 1 including open rotating end seals to prevent mud leakage into the oil cavity and to exclude penetration of the solid phase into the oil cavity.

12. An apparatus as claimed in claim 1 in which the alternator frequency is used to measure the input flow rate thus making it possible to detect leakage in the drilling column.

13. An apparatus as claimed in claim 1 including a disconnecter provided between the transmitter and the sensor unit enabling failure of any unit to be rapidly detected.

14. An apparatus as claimed in claim 1 in which the down hole unit is constructed in separable complete functional modules.

15. An apparatus as claimed in claim 6 in which the weight on bit sensor includes a reducer so that sensitive components can be pre-tightened before lowering the down hole unit into the well.

16. An apparatus as claimed in claim 16 in which the weight on bit sensor includes a temperature sensor inside the casing of the down hole unit which with the annulus temperature sensor makes it possible to eliminate temperature error of the weight-on-bit measuring data channel.

17. An apparatus as claimed in claim 1 in which the hydraulic unit includes a rotating disc valve, the axis of the valve being perpendicular to the axis of the down hole unit.

18. A measurement while drilling apparatus constructed and arranged for use and operation substantially as herein described and with reference to the accompanying drawings.

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The Patent Office

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Claims searched: 1-18

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): E1F (FHK)

Int Cl (Ed.6): E21B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2150172 A	(NL Sperry-Sun Inc.) Whole document	1,2
X	GB 2127461 A	(Dresser Industries Inc.) Whole document	1
X	GB 2123458 A	(NL Sperry-Sun Inc.) Whole document	1
X	GB 2087951 A	(Russell Attitude Systems Ltd.) Whole document	1
X	GB 2058171 A	(Dresser Industries Inc.) Whole document	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.